

Sensitivity Analysis of a Sparse Array of Antennas

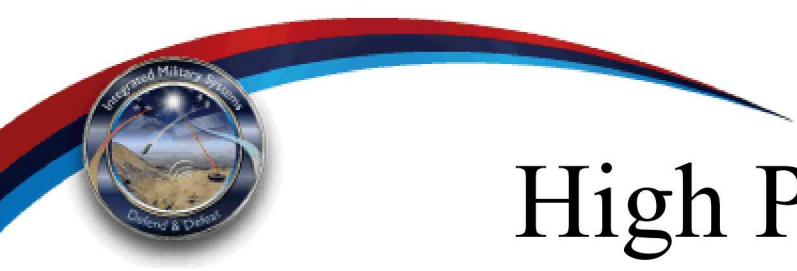
Presented to DEPS on April 10, 2019

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Larry Bacon, DE Assessments,
Sandia National Laboratories, Albuquerque, NM

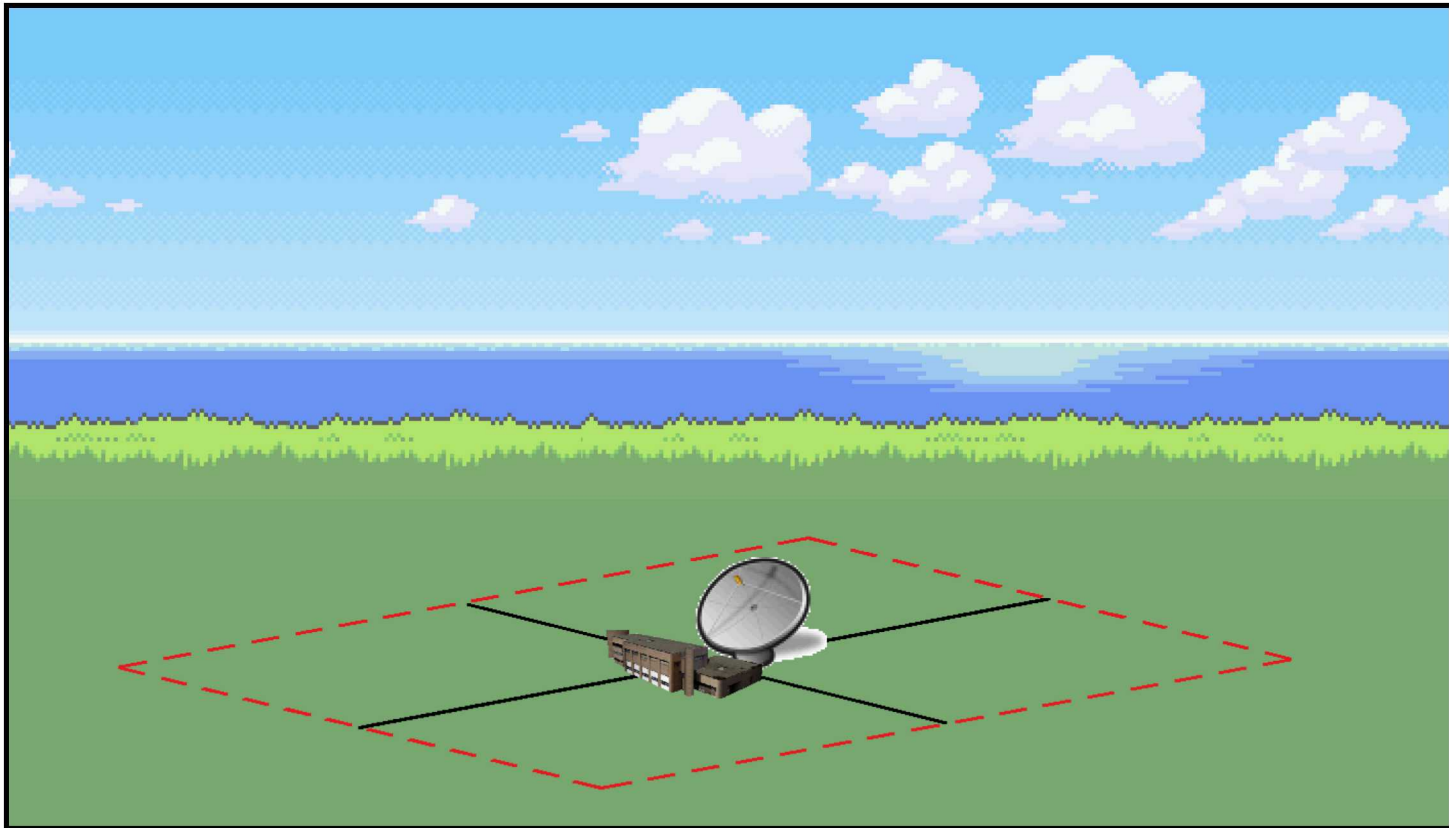


Why Sparse Arrays?

- Issues Delivering Power at Distance
 - Limits of Physics
 - Pushing the Tech Envelope
- Advantages of SA
 - Scalability / Mobility / Reliability / Repeatability / Robust
 - Smaller / Less Obtrusive
- Disadvantages of SA
 - Data Communication Requirements
 - Near Field Focusing / Phase Control at a Distance



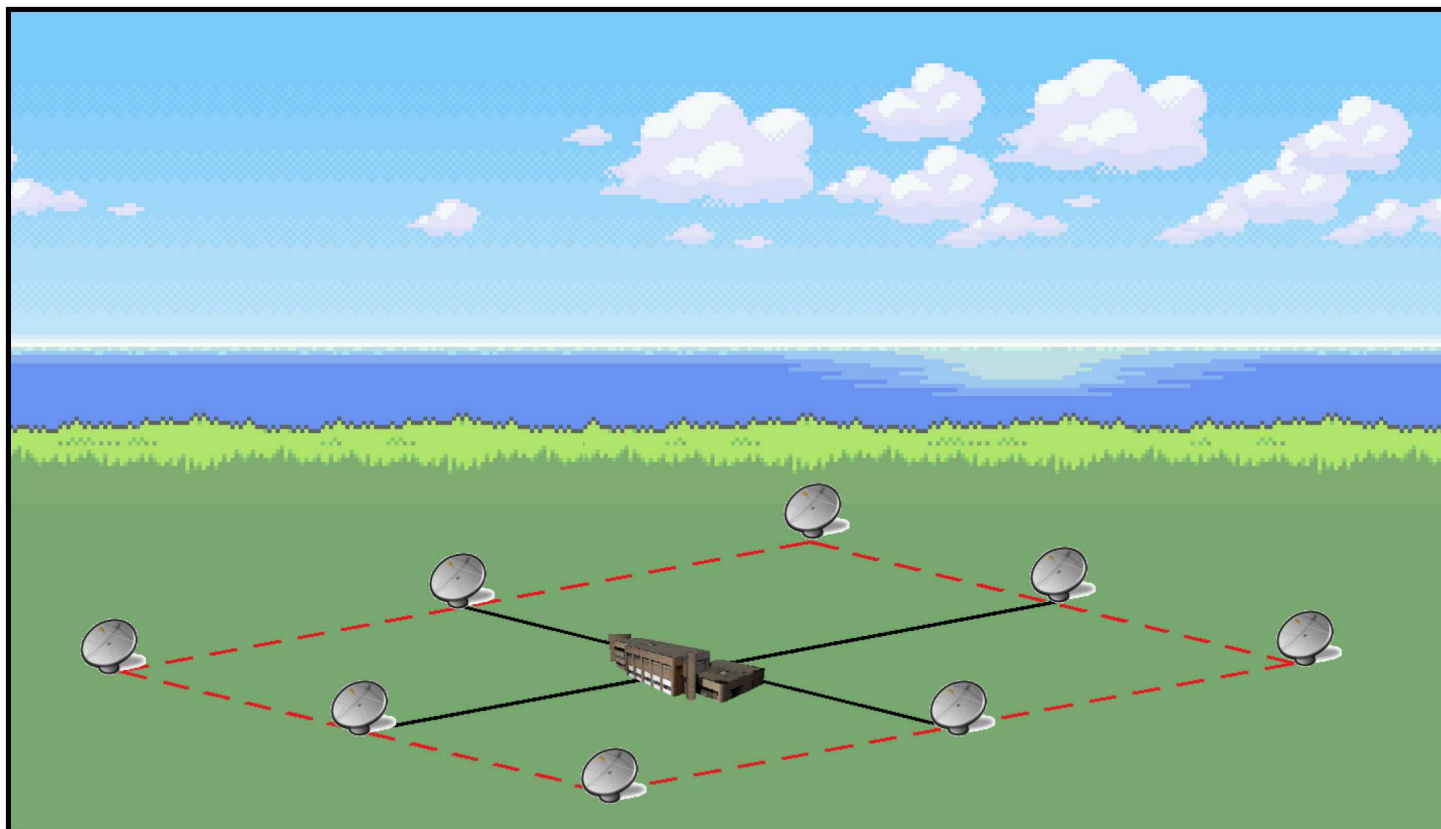
High Power Defense



Defensive Scenario – Original



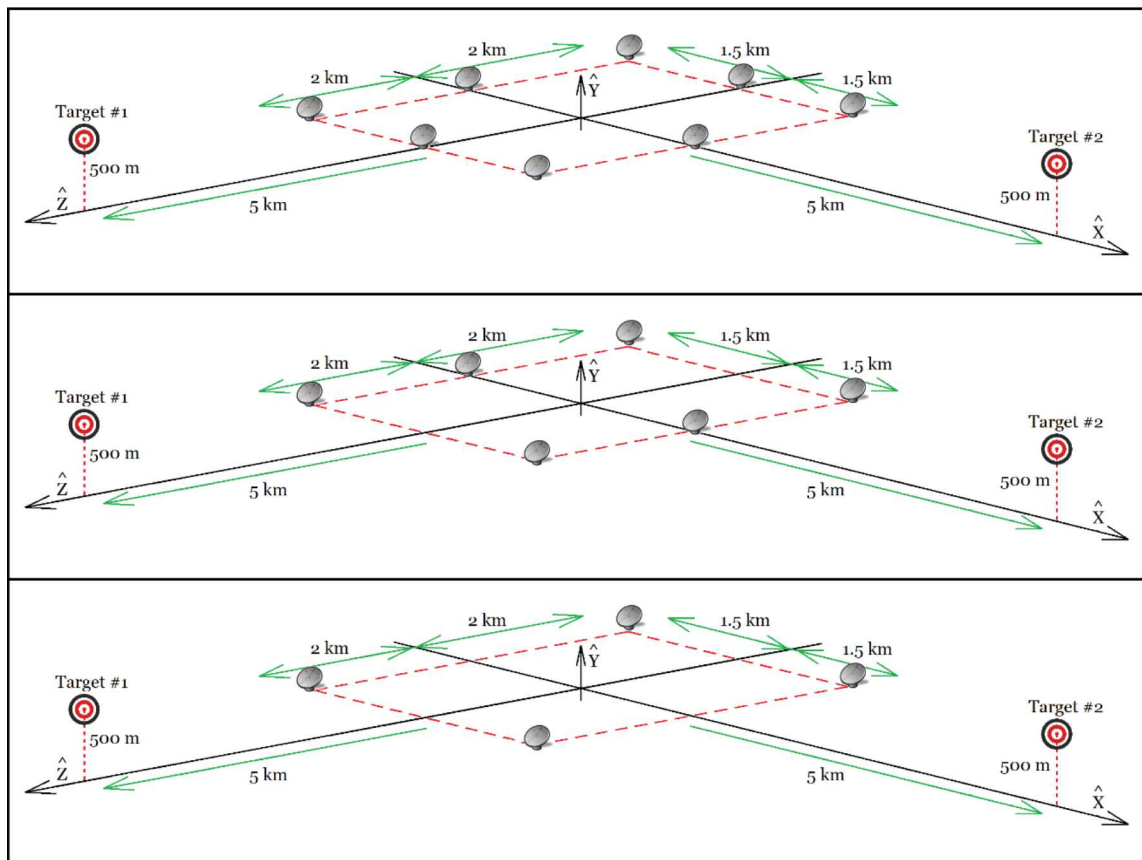
High Power Defense / N



Defensive Scenario – Sparse Array



Scenarios Analyzed: Arrays with 8, 6, & 4 Antennas

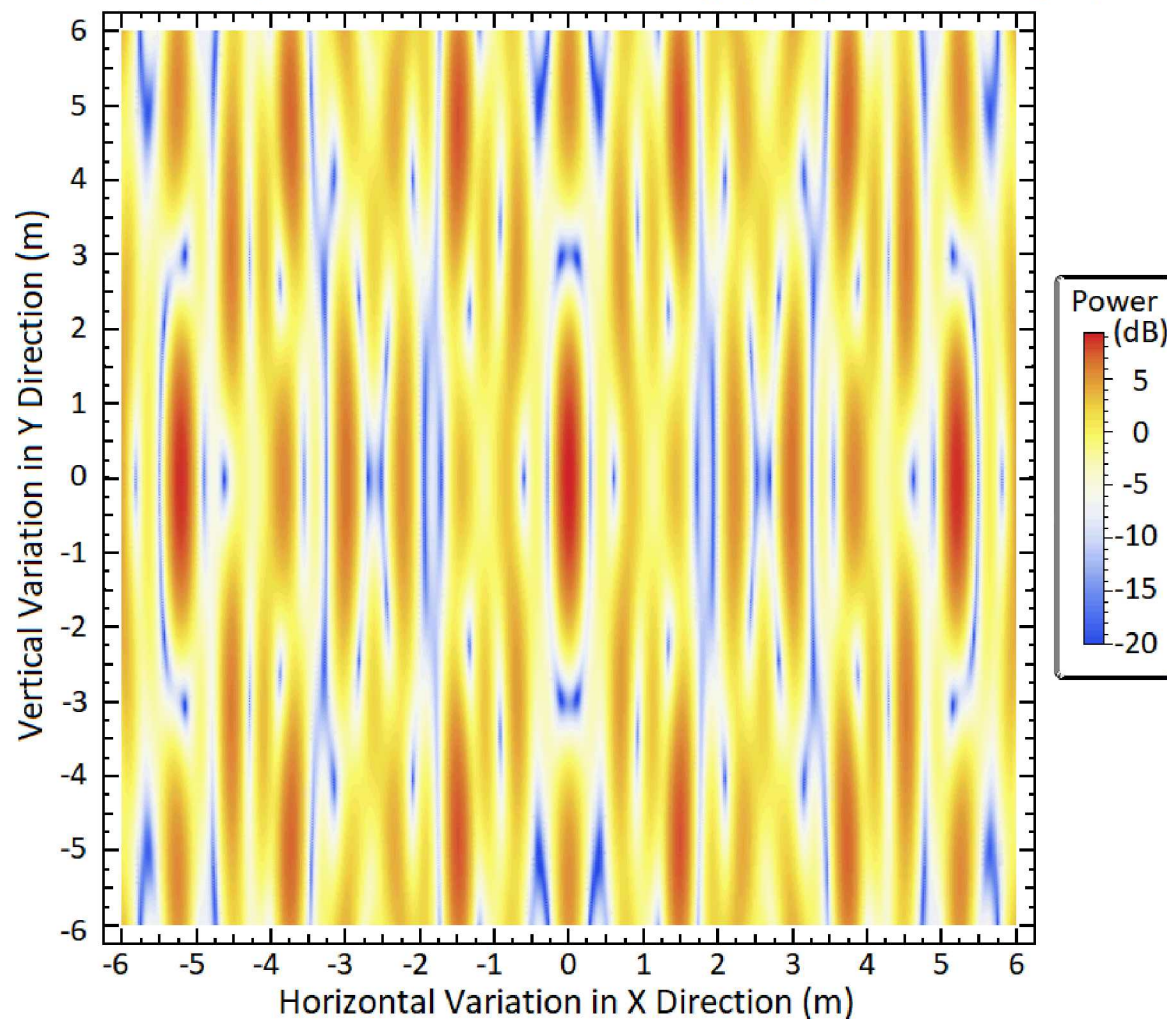


Array and Target Configurations/Locations



Target Location Field Variations

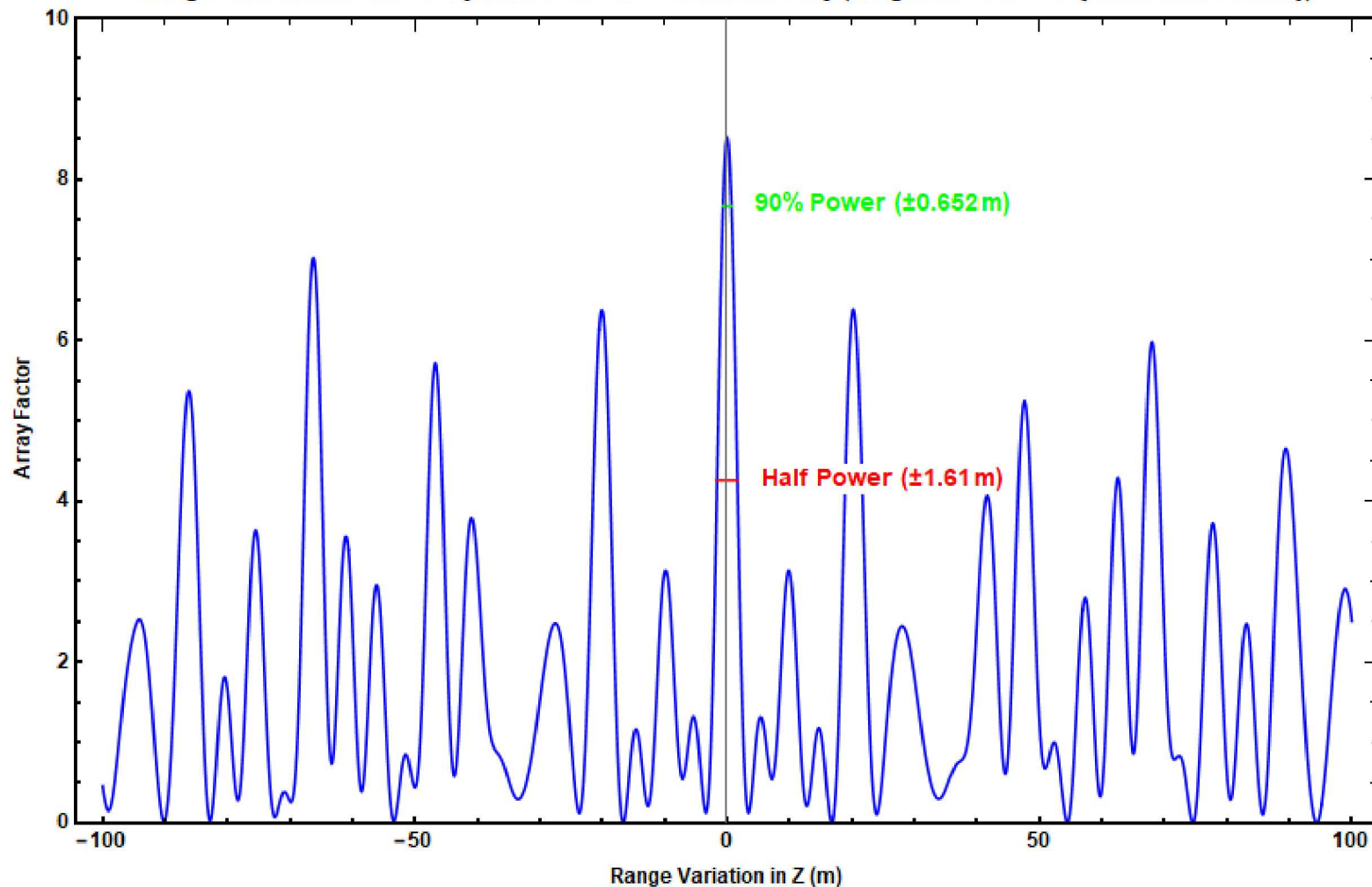
Spatial Variation of the Array Factor for an 8 Element Array (Target at 5 km $\rightarrow$ {0m, 500m, 7000m})





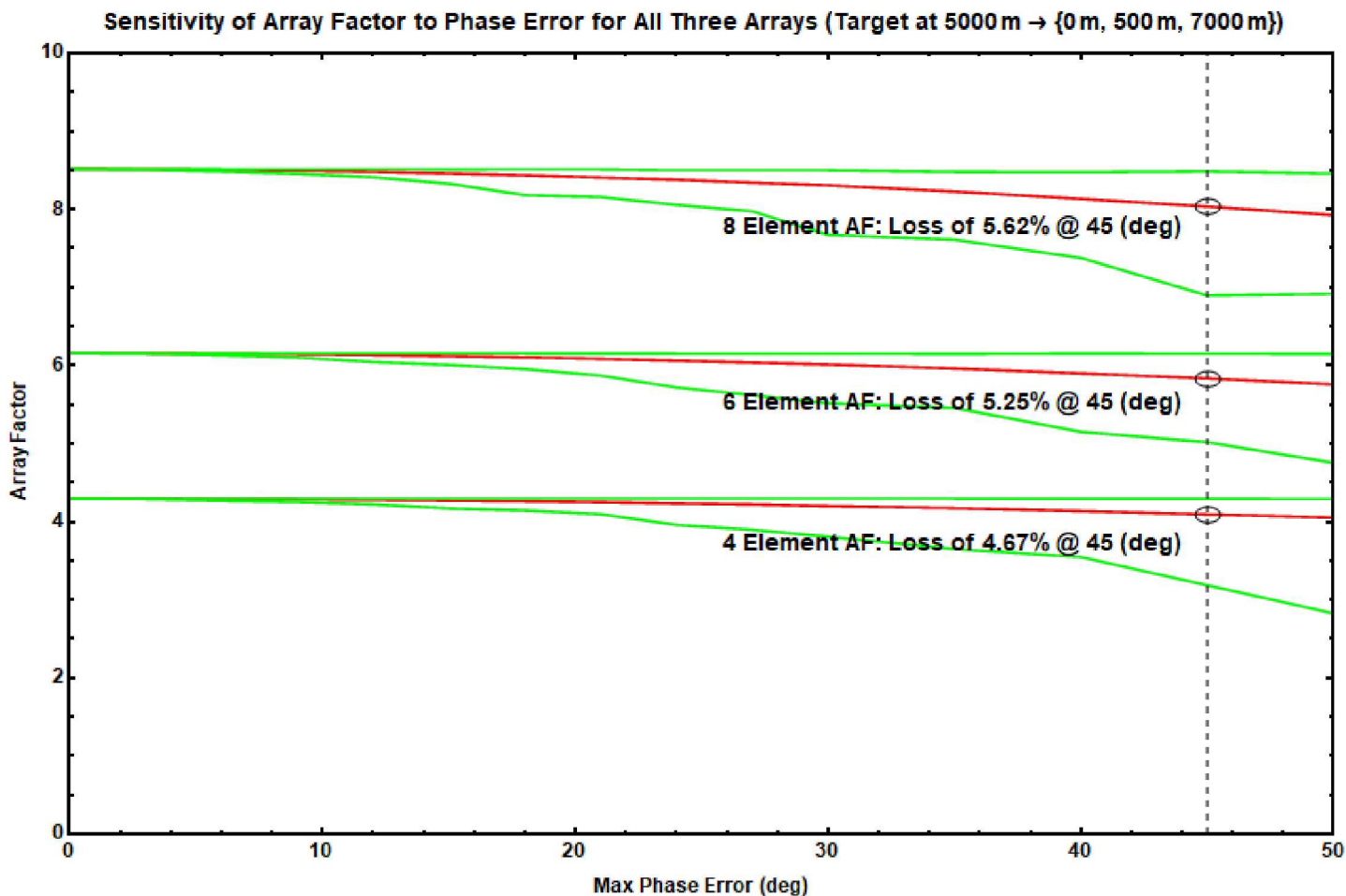
Target Location Field Variations

Range Variation of the Array Factor for an 8 Element Array (Target at 5000 m $\rightarrow$ {0 m, 500 m, 7000 m})



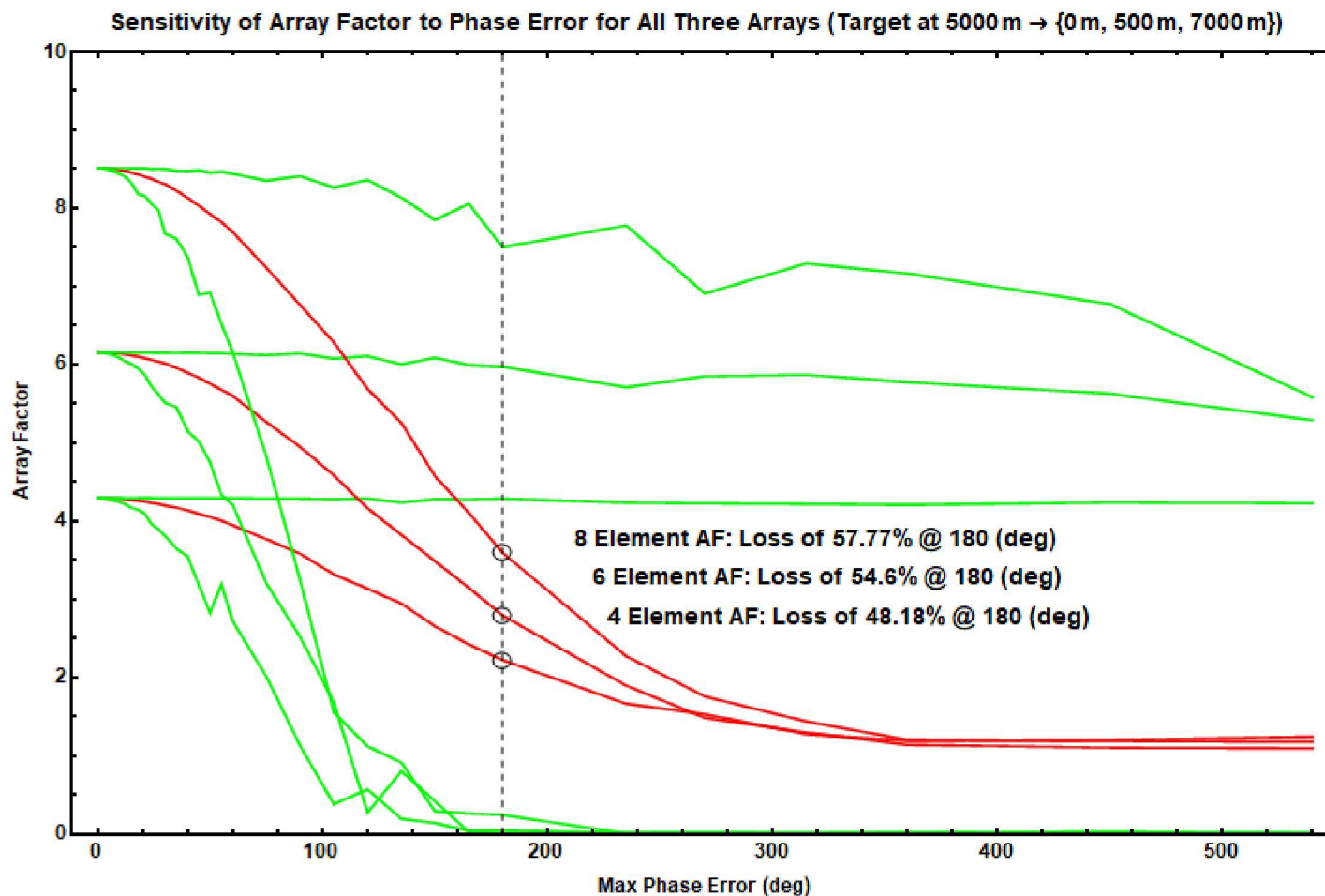


Analysis: Phase Error @ Target



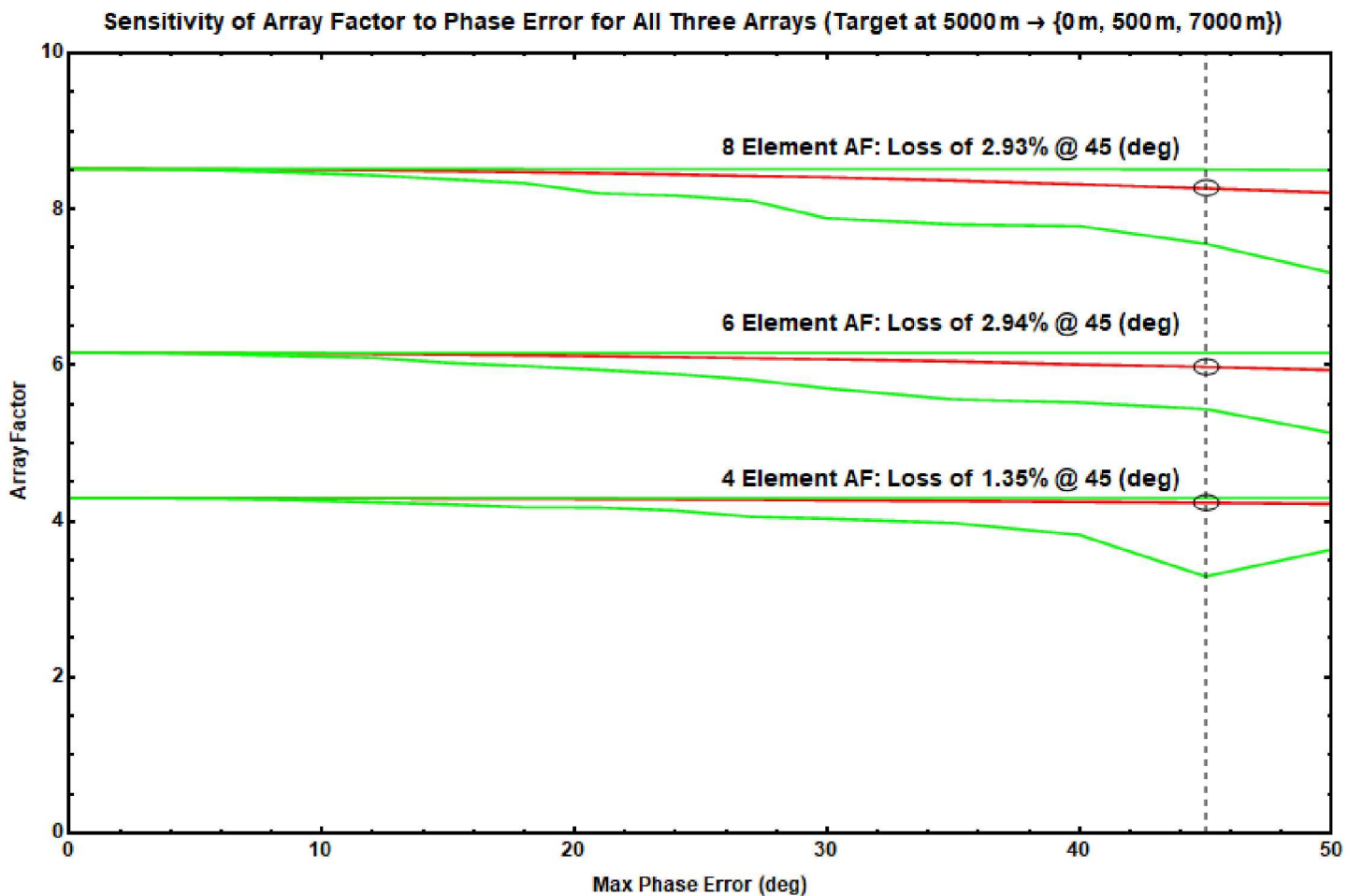


Analysis: Phase Error @ Target



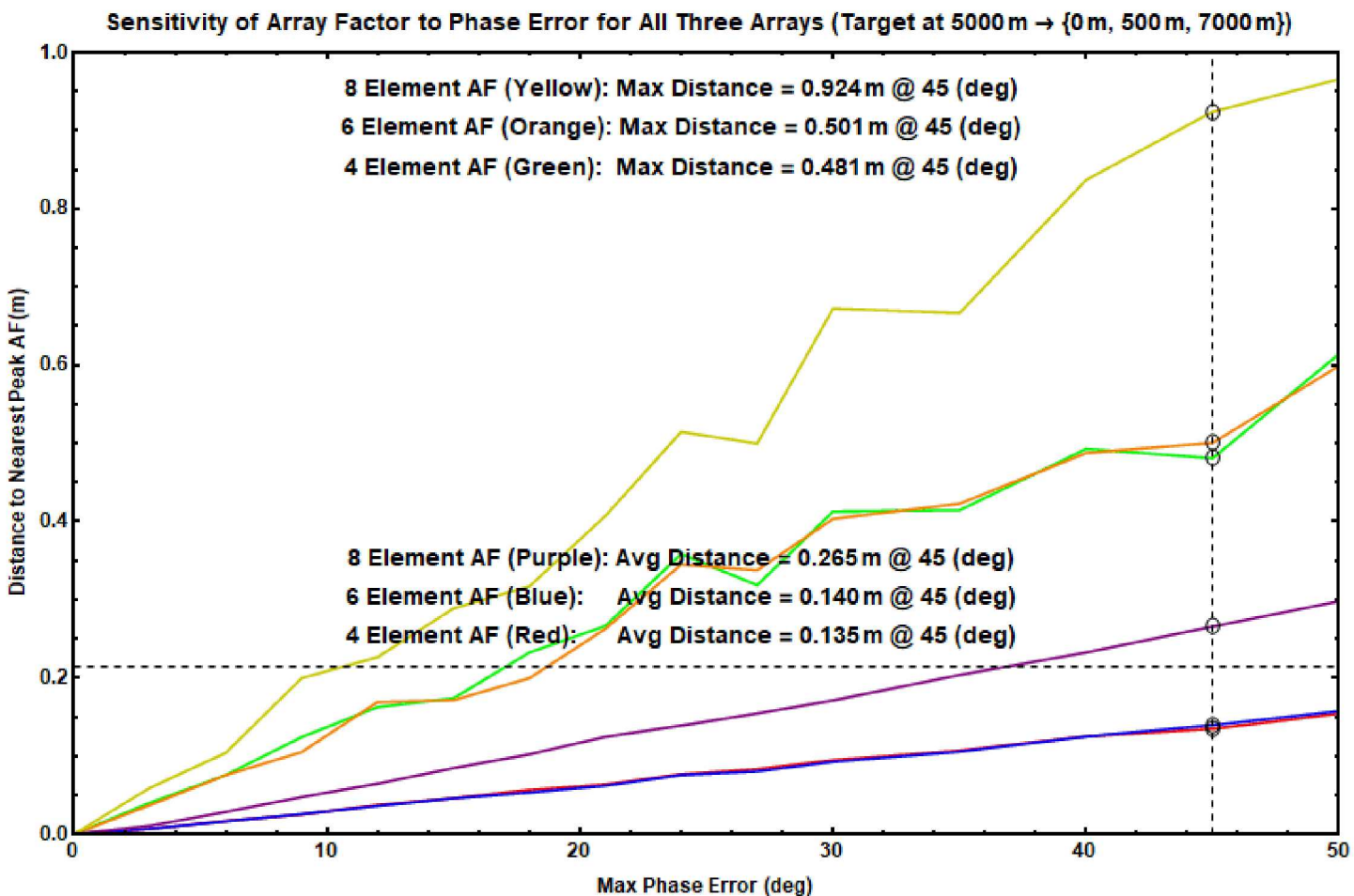


Phase Error: Nearest Local Max





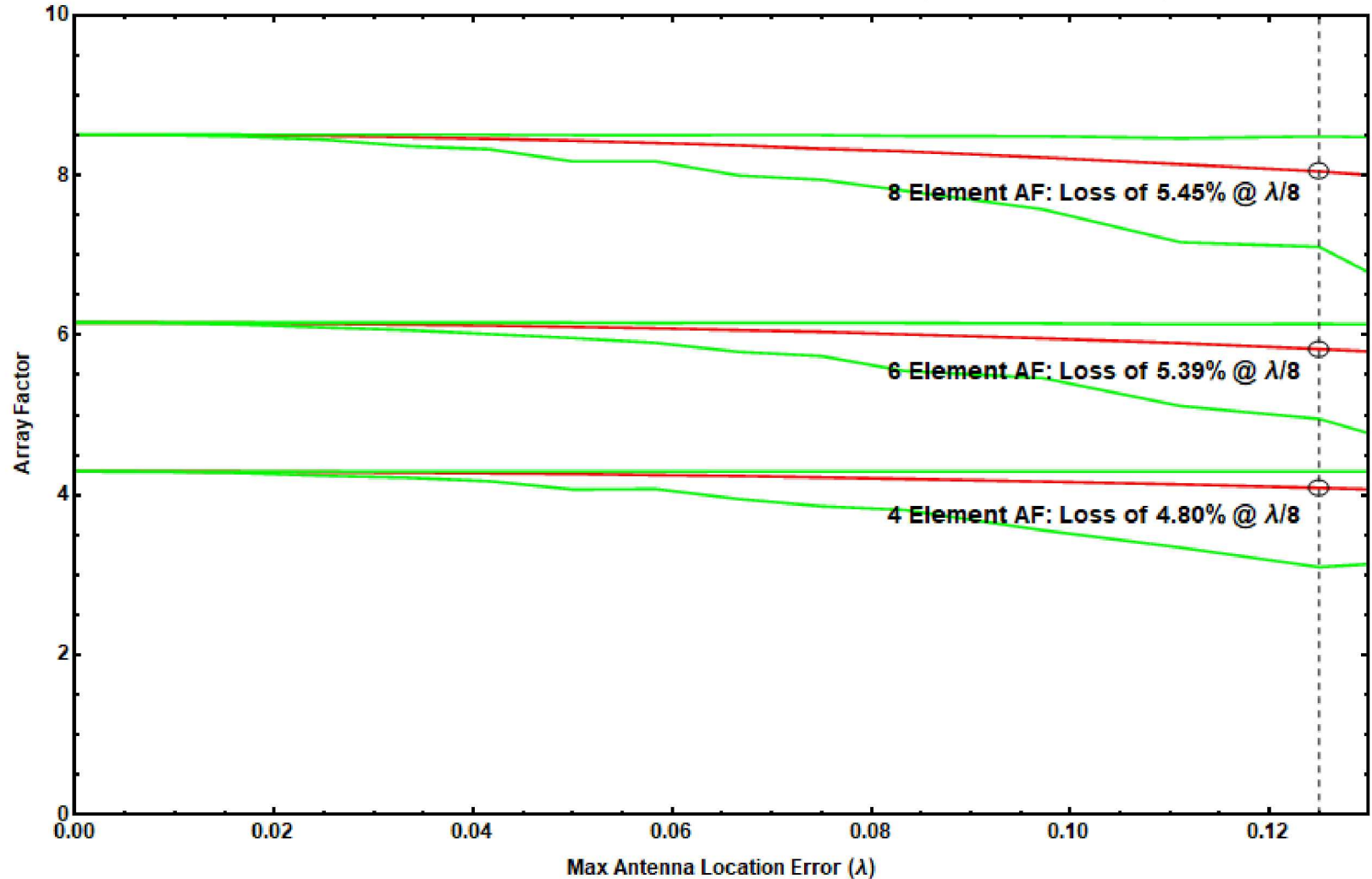
Phase Error: Nearest Local Max





Analysis: Location Error @ Target

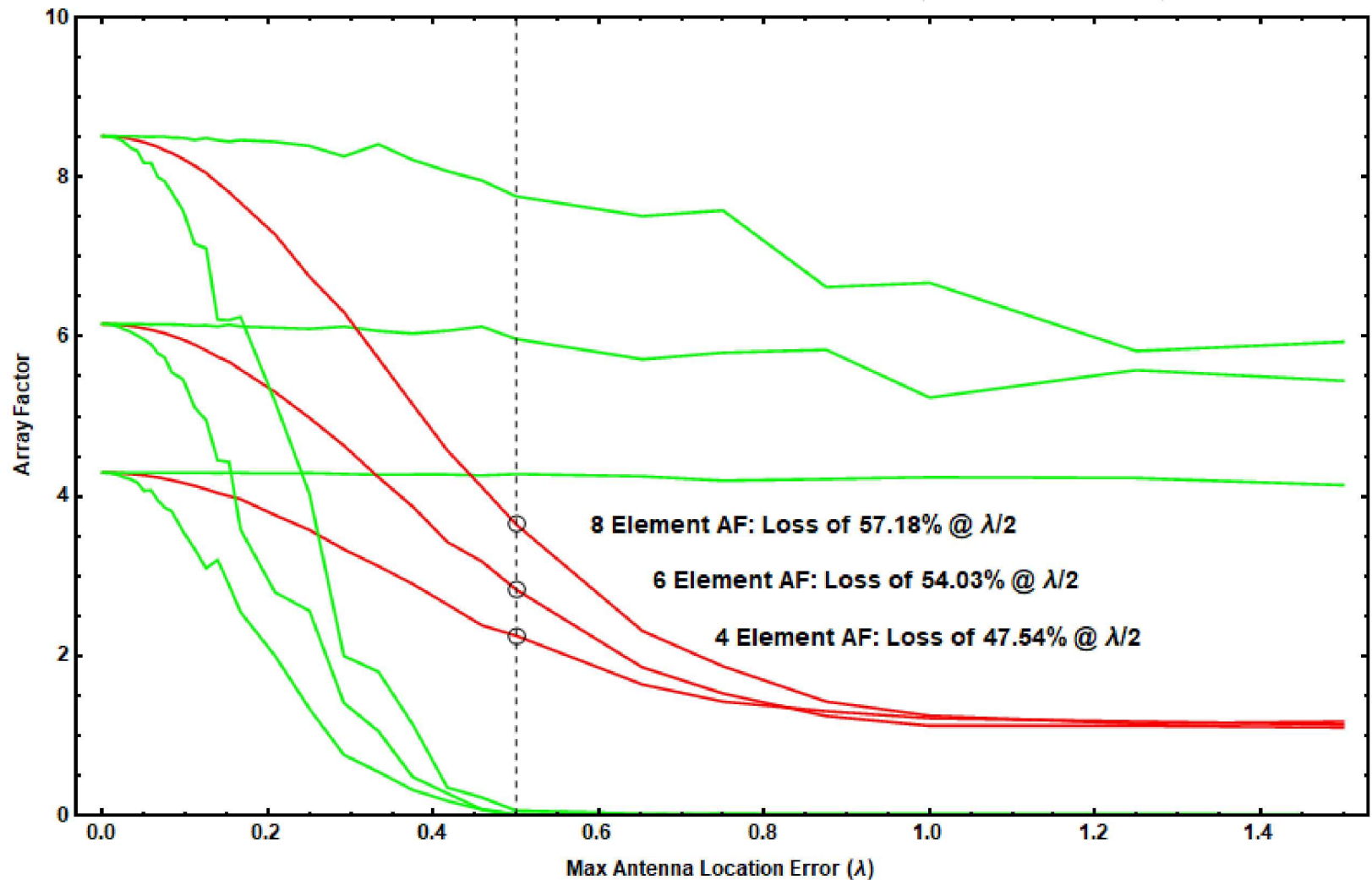
Sensitivity of Array Factor to Antenna Location Error for All Three Arrays (Target at 5000 m $\rightarrow$ {0 m, 500 m, 7000 m})





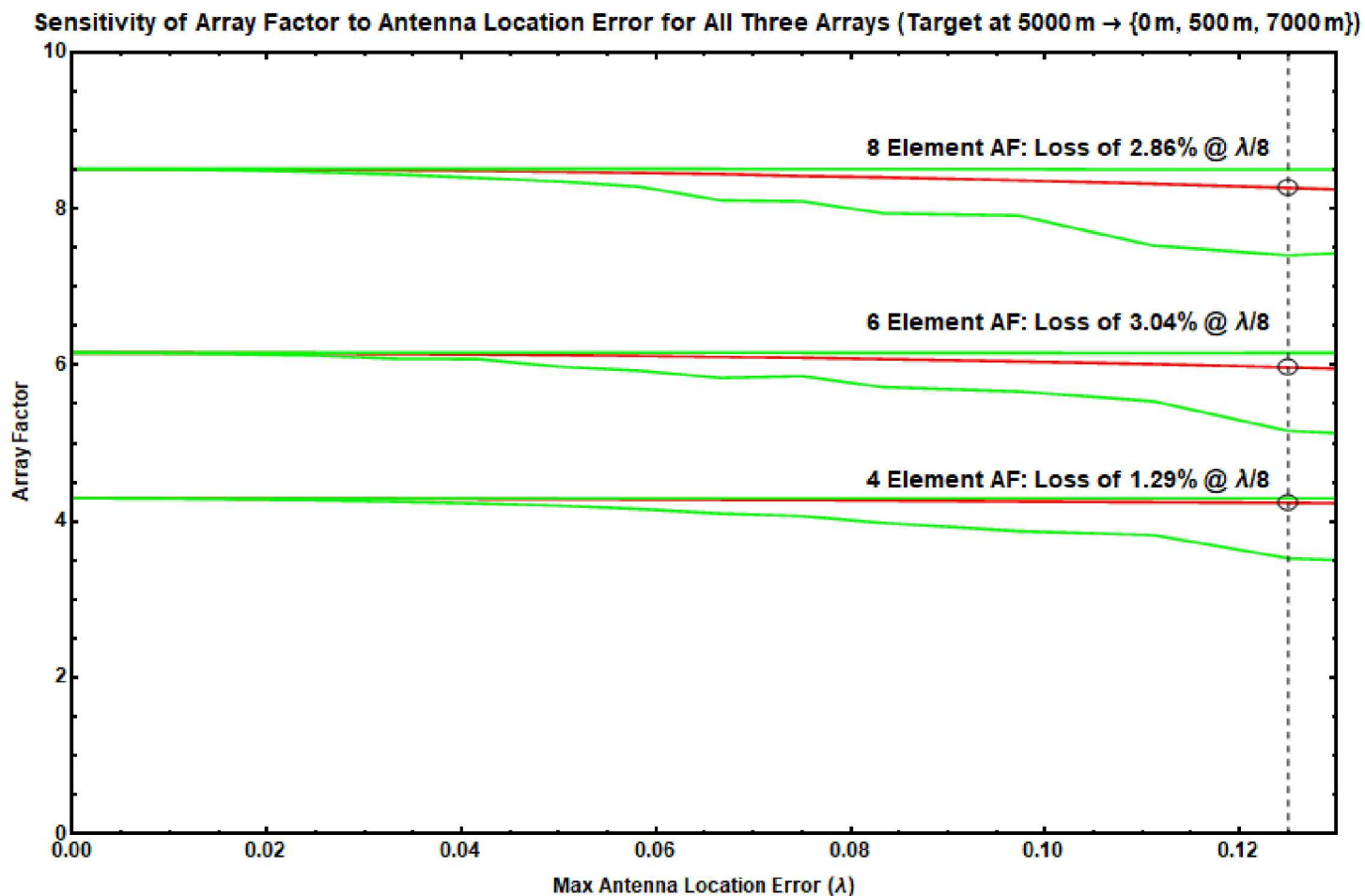
Analysis: Location Error @ Target

Sensitivity of Array Factor to Antenna Location Error for All Three Arrays (Target at 5000 m → {0 m, 500 m, 7000 m})





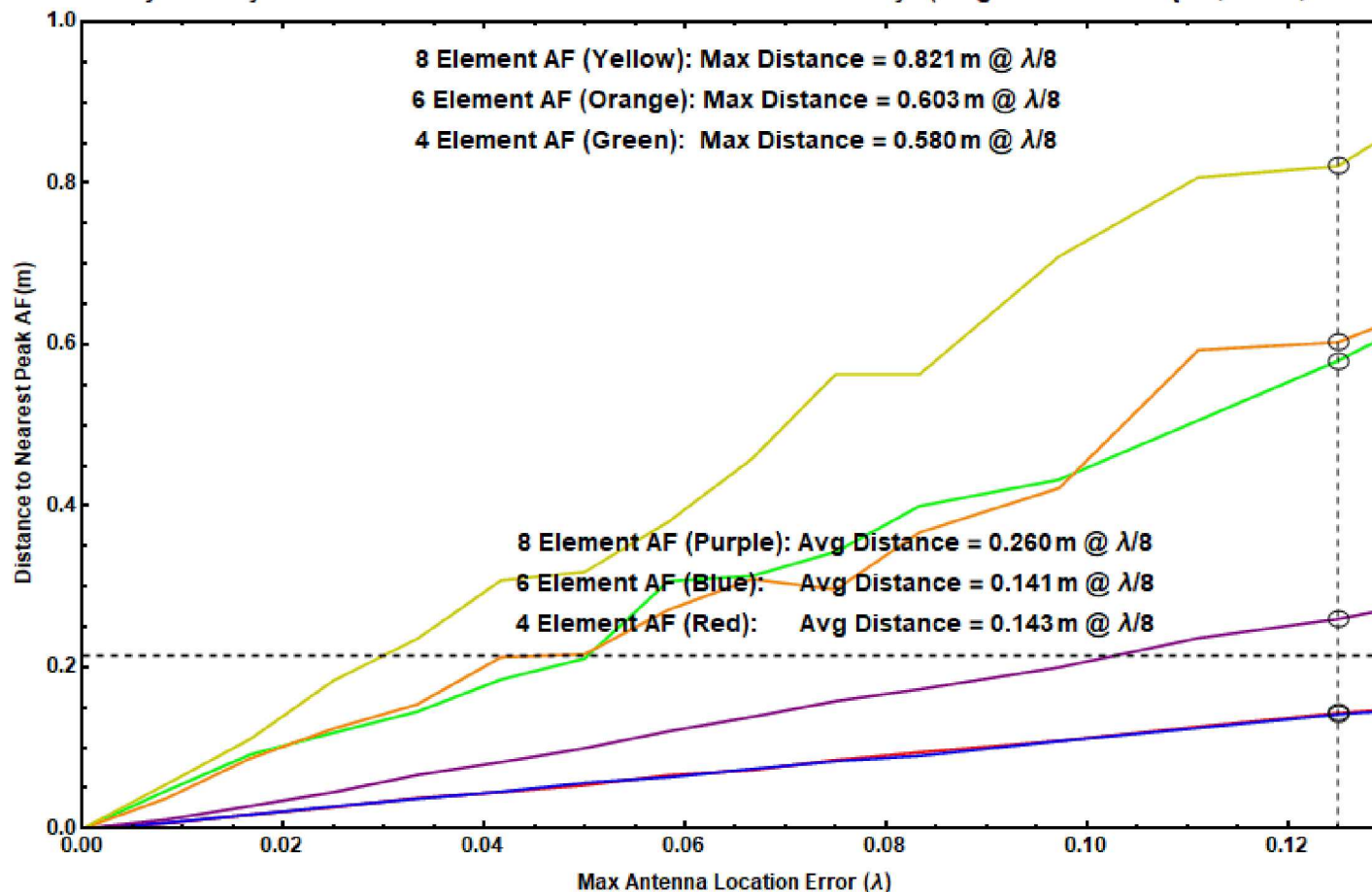
Location Error: Nearest Local Max





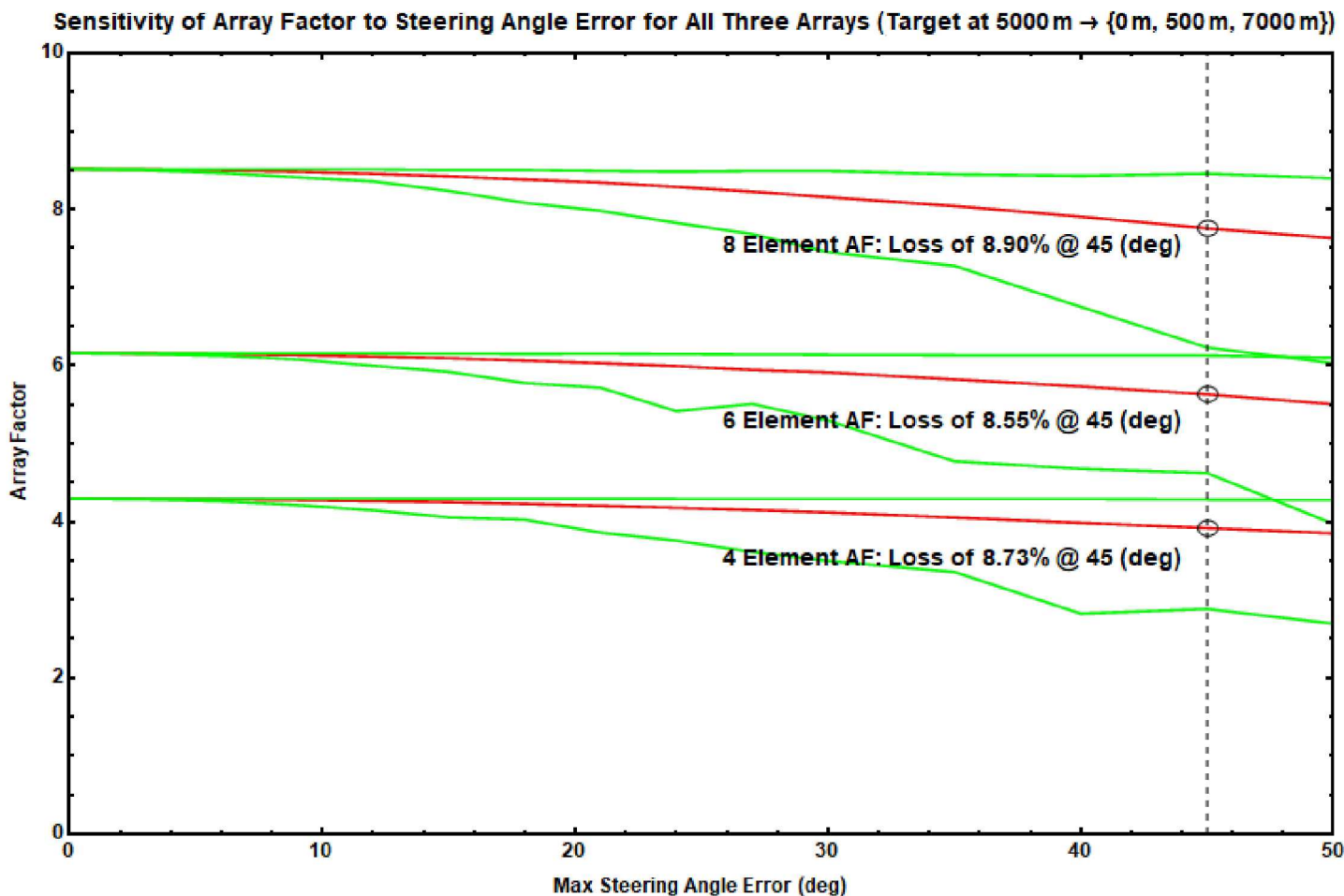
Location Error: Nearest Local Max

Sensitivity of Array Factor to Antenna Location Error for All Three Arrays (Target at 5000 m $\rightarrow$ {0 m, 500 m, 7000 m})





Steering Angle Error @ Target





Summary

- Target Location Errors
 - Elevation: exaggerated by dipole pattern
 - Azimuth: depends on target size
- Antenna Phase Errors / Antenna Location Errors
 - Essentially Equivalent
- Antenna Steering Errors
 - Needs to be recalculated with more realistic antenna patterns



Implications

- Target Location Errors
 - 50% Bubble: 27cm x 2.9m x 3.2m (x-y-z)
 - 90% Bubble: 11cm x 1.2m x 1.3m (x-y-z)
- Antenna Phase Errors
 - 60° – 81° deg of error -> 0.11 -0.15 ns “jitter” limit
 - Laser triggered switches can do this
- Antenna Location Errors
 - Translates to near equivalent values (L -> 360) as Phase Errors
 - Well below GPS accuracy but “correctable” during array set-up
- Antenna Steering Errors
 - Exaggerated by dipole pattern



Local Maxima

- Explanation
 - Just because AF drops at exact target location...
- Antenna Phase Errors
 - Exact: Can get 90% of AF with 60 deg error
 - Local: Can get 90% of AF at 30-35 cm with 80+ deg error
- Antenna Location Errors
 - Exact: Can get 90% of AF with 60 deg error
 - Local: Can get 90% of AF at 30-35 cm with 80+ deg error
- Antenna Steering Errors
 - Exact: Can get 92% of AF with 45 deg error
 - Local: Incomplete – SW optimization issues



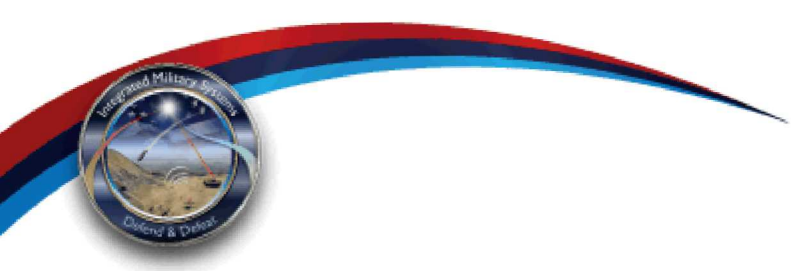
Conclusions

- The dispersed nature of the SA does not preclude the ability to produce a coherent field at the target location
 - Phase “jitter” of sources is biggest hurdle
- SA can be effective even if error-levels are not “pristine”
 - Only 5 – 10% AF loss experienced with 60 – 70 deg errors
 - Local maximum reduces AF loss 1/3 to 1/2 within 30-35 cm
- General Conclusions
 - No “deal-breakers” seen
 - Phase-locking sources is the longest-pole (so far)
 - More analysis is needed



Future Work

- Future Plans
 - Updated Antennas
 - Additional System Characteristics
 - Sensitivity due to Antenna Slew Rates
 - Sensitivity due to Output Power Variability
 - Range Variability of System Sensitivities
- Other Plans for Improvement
 - Better SW Optimization Routines



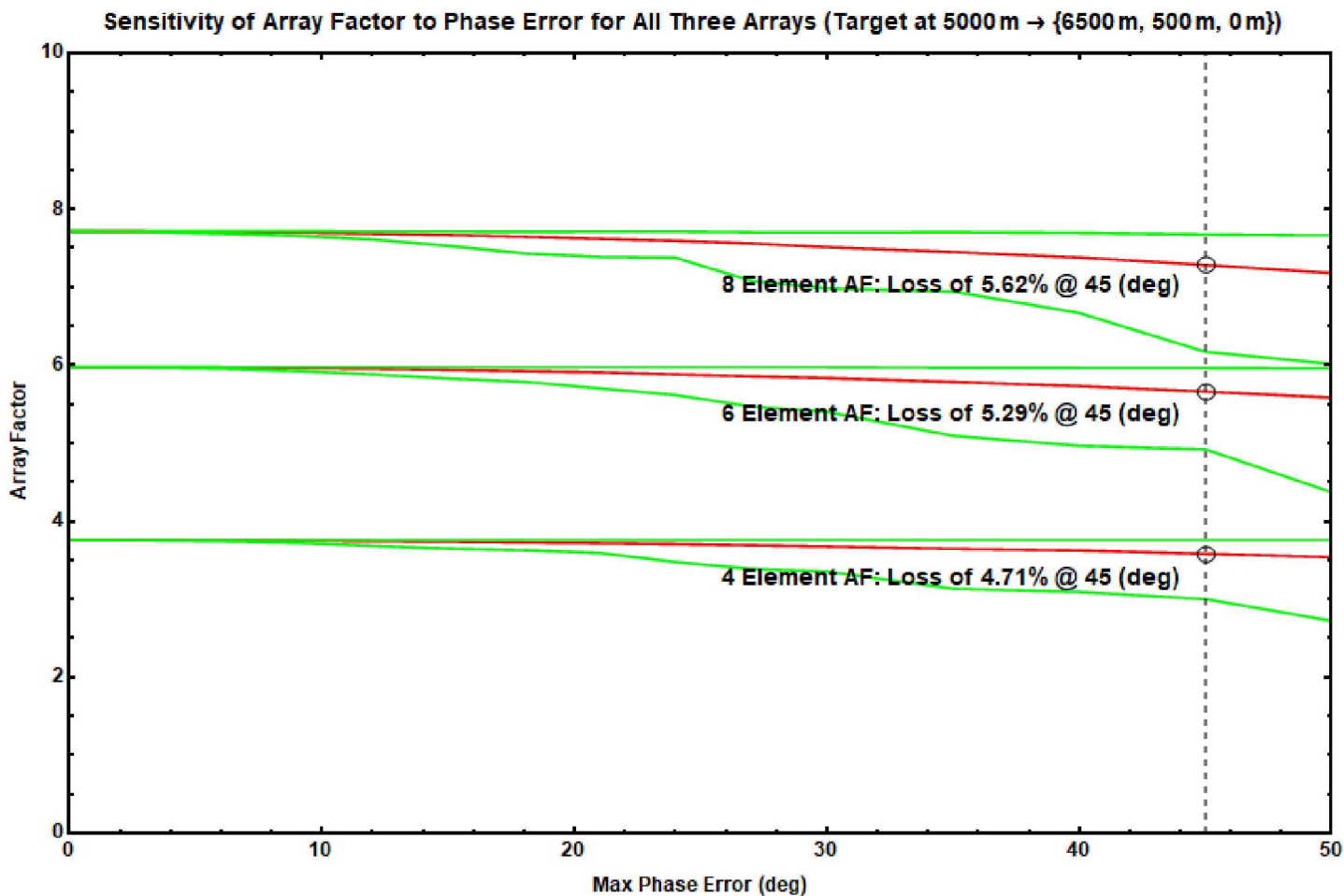
QUESTIONS?



Extra Slides

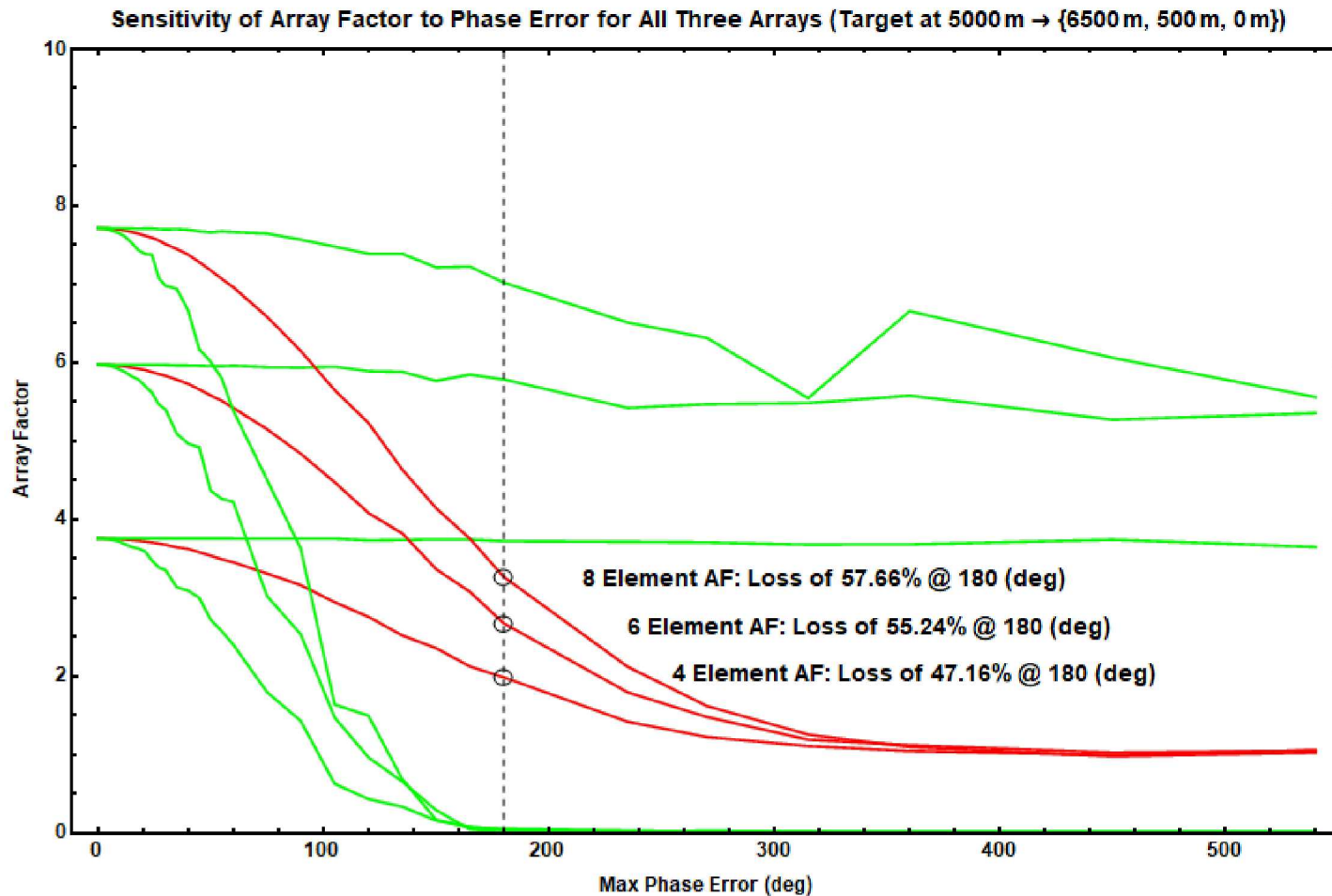


Analysis: Phase Error @ Target



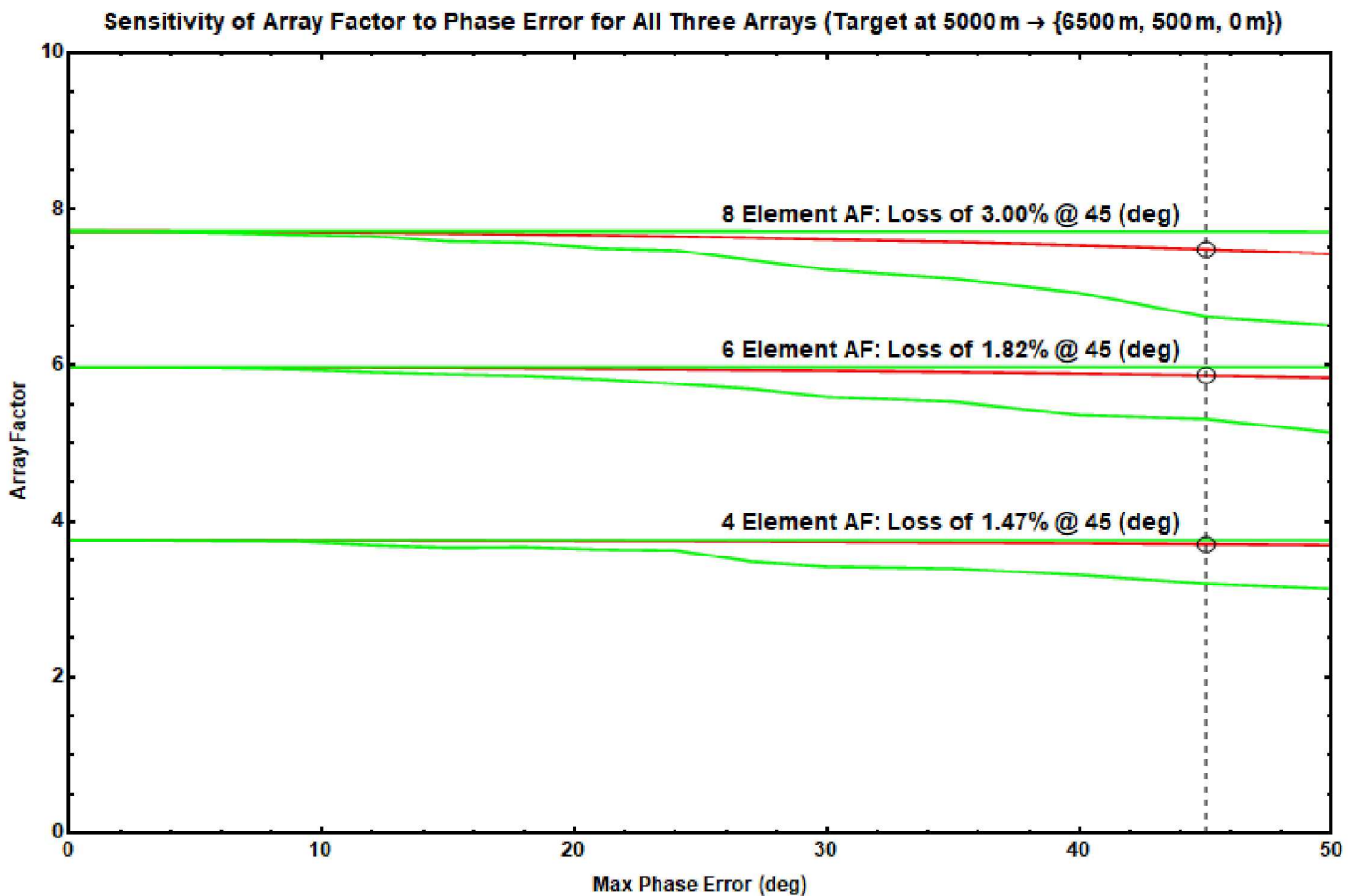


Analysis: Phase Error @ Target



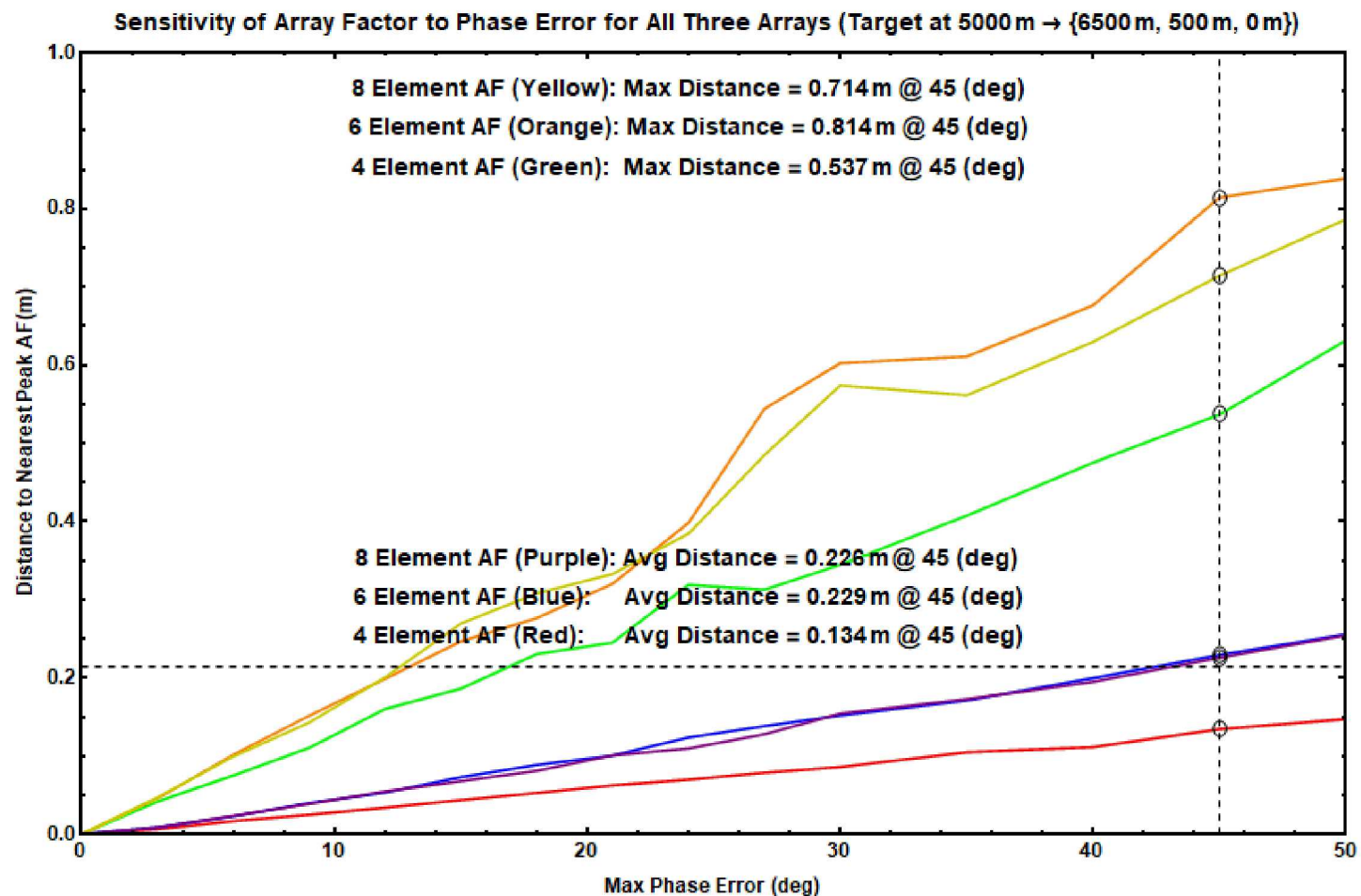


Phase Error: Nearest Local Max





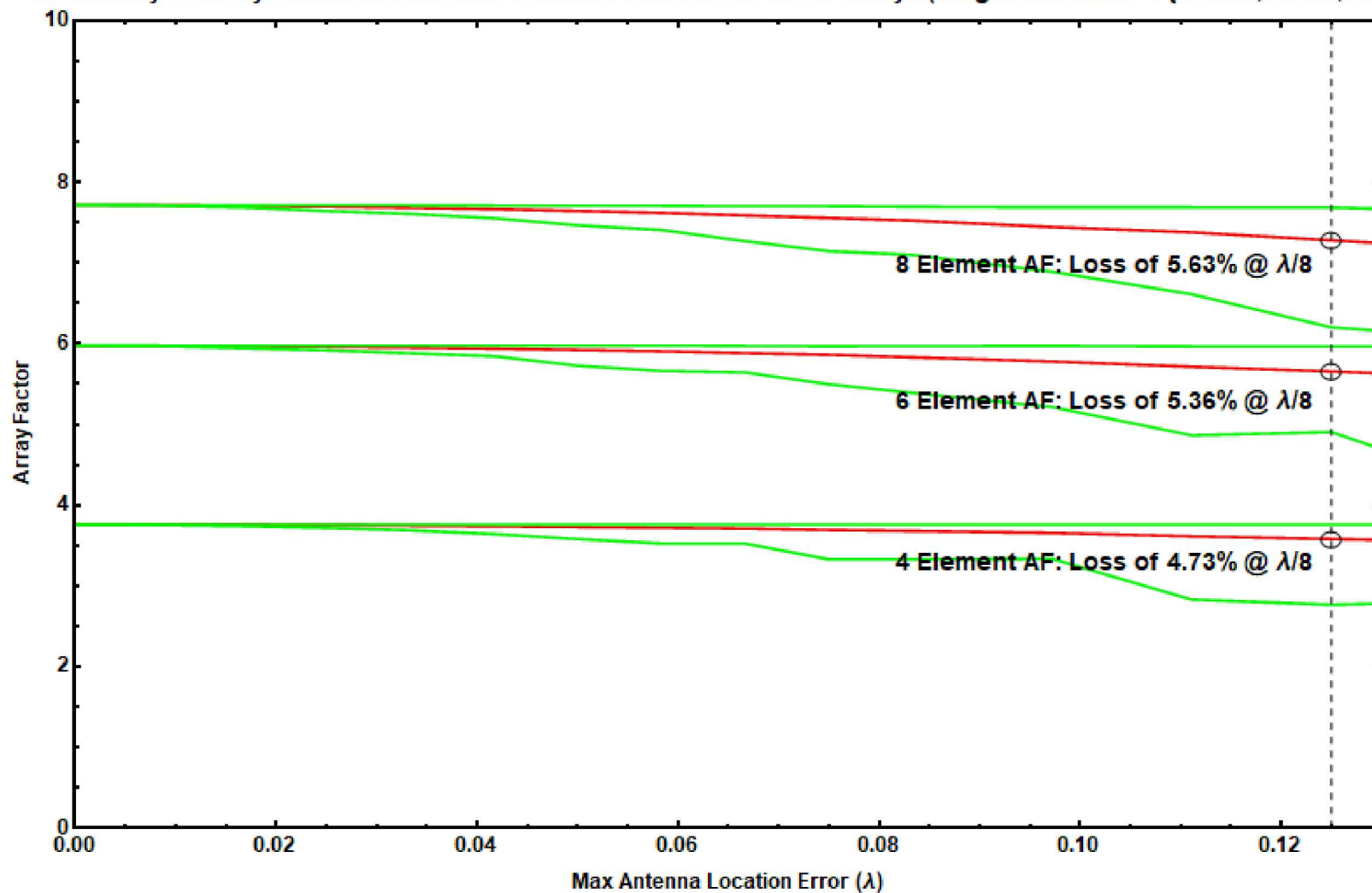
Phase Error: Nearest Local Max





Analysis: Location Error @ Target

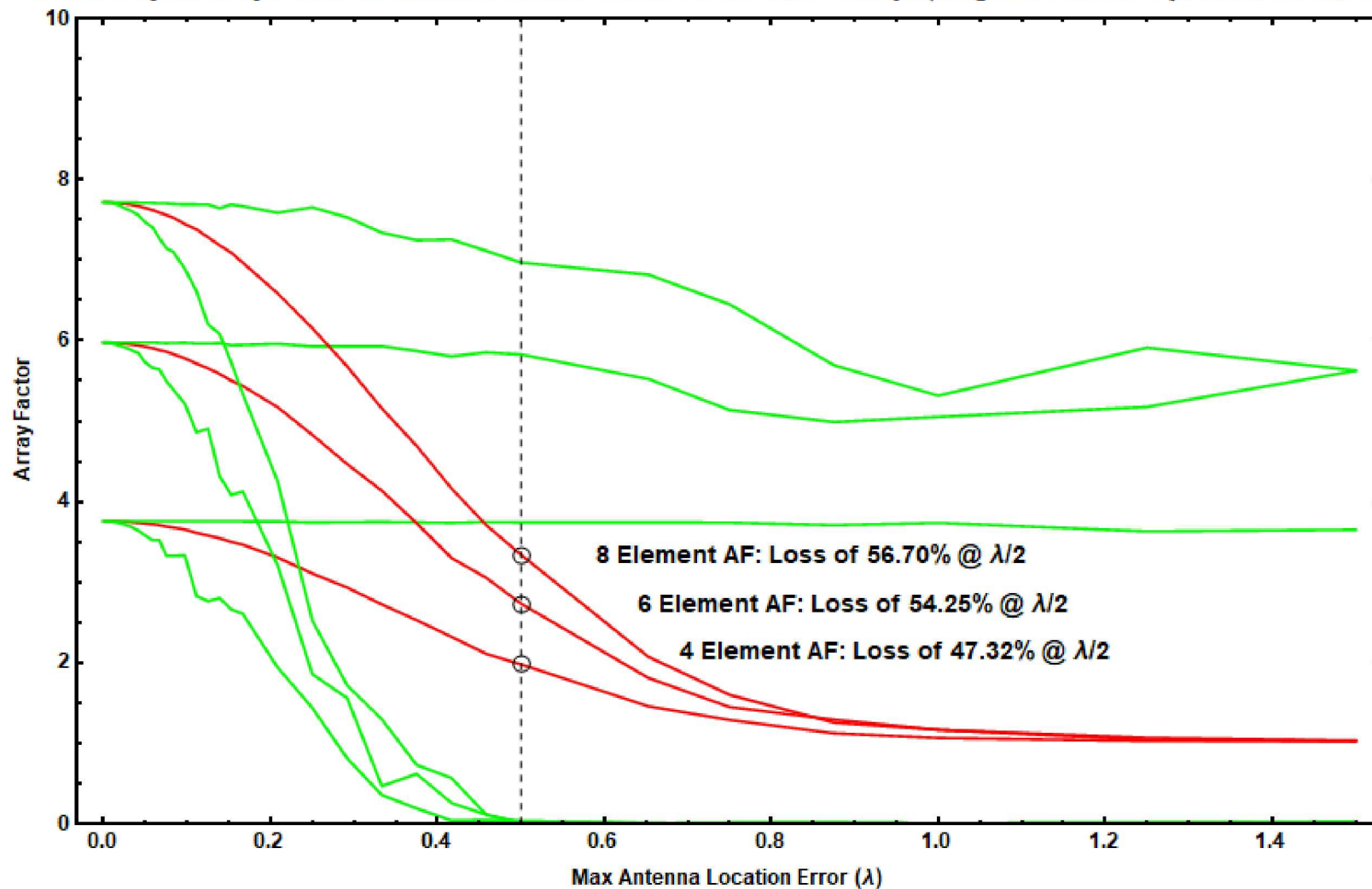
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Analysis: Location Error @ Target

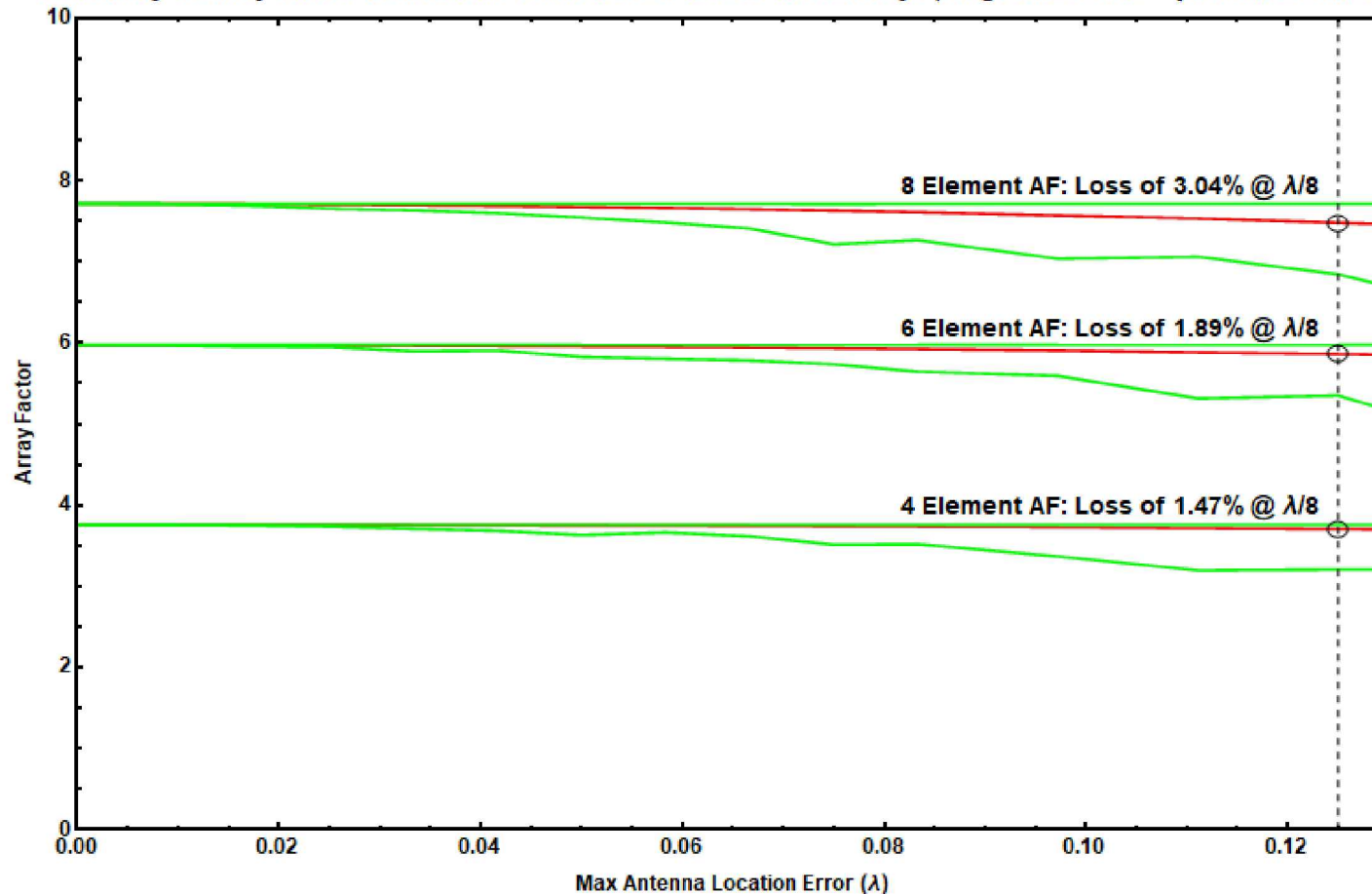
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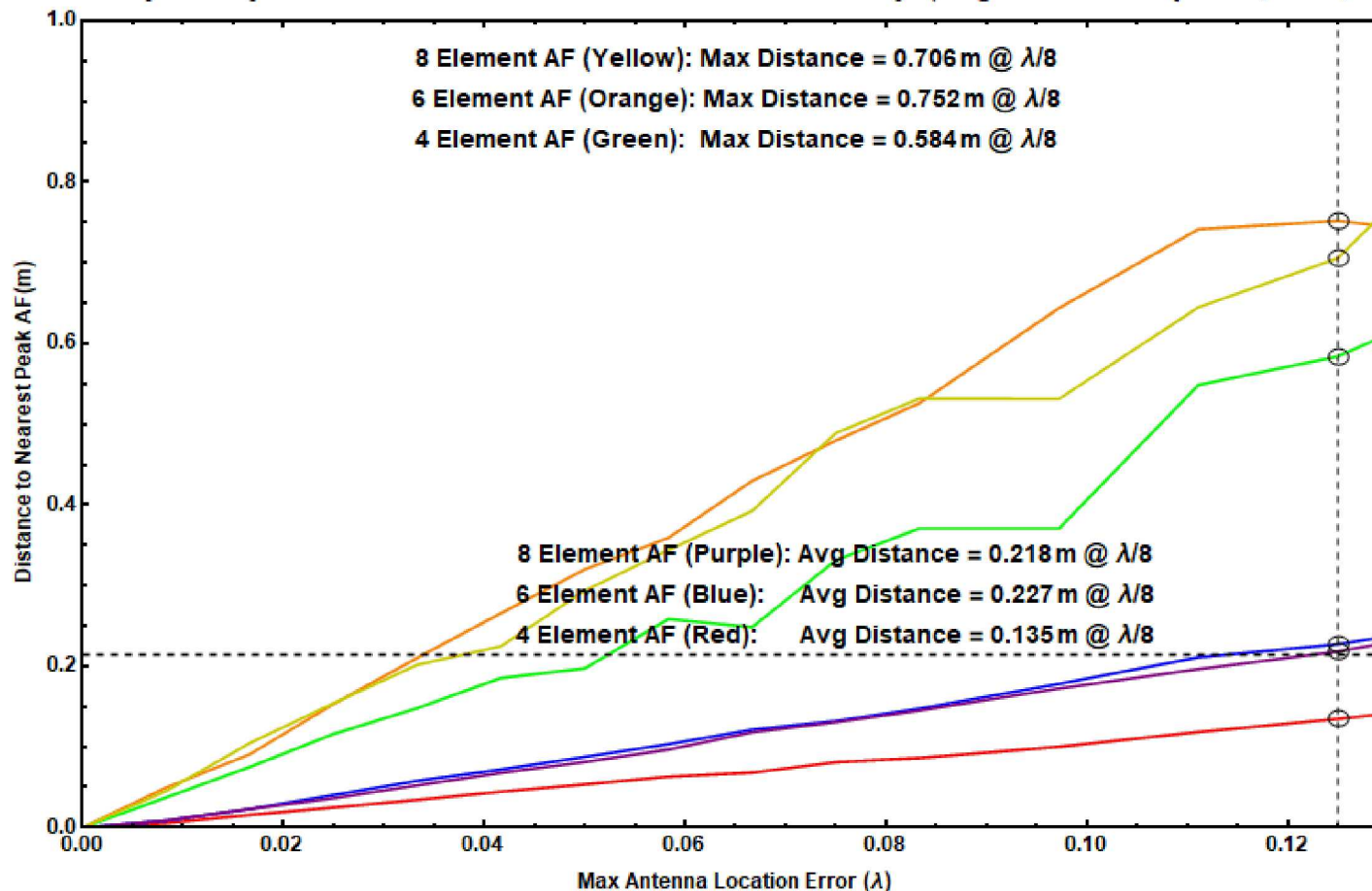
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Location Error: Nearest Local Max

Sensitivity of Array Factor to Antenna Location Error for All Three Arrays (Target at 5000 m $\rightarrow$ {6500 m, 500 m, 0 m})





Steering Angle Error @ Target

